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BENCHMARK CALCULATIONS OF POWER DISTRIBUTION WITHIN ASSEMBLIES

(Specification)

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1. INTRODUCTION

The main final objective of this Benchmark is to compare different techniques of fine flux distribution assessment within assemblies, using standard diffusion, nodal or transport schemes.

In order to avoid, at first, difficulties for intercomparison due to different calculation routes (Homogenization, Transport corrections, Fine Flux Reconstruction...), it seems appropriate to begin with simple (if not Trivial) calculation conditions.

Thus, calculations should be run on a first series of configurations, presented in section 4, using a given set of macroscopic cross-sections for elementary cells.

A possible evolution of this benchmark is also proposed, based upon the use of heterogeneous X-sections.

2. HOMOGENEOUS CELLS - NEUTRON CROSS SECTIONS

Different homogeneous cells are considered with the following neutron cross sections :

Cell type	D1 (cm)	SA1 (cm^{-1})	SR (cm^{-1})	NSF1 (cm^{-1})	D2 (cm)	SA2 (cm^{-1})	NSF2 (cm^{-1})
U : UO_2 Fuel	1.2	0.010	0.020	0.0050	0.4	0.100	0.125
P1 : Peripheral MOX Fuel	1.2	0.015	0.015	0.0075	0.4	0.200	0.300
P2 : Intermediate MOX Fuel	1.2	0.015	0.015	0.0075	0.4	0.250	0.375
P3 : Central MOX Fuel	1.2	0.015	0.015	0.0075	0.4	0.300	0.450
X : Guide Tube	1.2	0.001	0.025	0	0.4	0.02	0
R : Reflector	1.2	0.001	0.050	0	0.2	0.04	0
C : Moveable Fission Chamber	1.2	0.001	0.025	1.E-7	0.4	0.02	3.E-6
A : Absorber (AIC)	1.2	0.040	0.010	0	0.4	0.8	0

With :

- 1 for the "fast" energy group
- 2 for the "thermal" energy group
  (Energy cut off at 0.625 eV.)

- D1, D2 — Diffusion coefficients
- SA1, SA2 — Absorption cross sections
- SR — removal cross section ($1 \rightarrow 2$)
- NSF1, NSF2 — Fission cross sections multiplied by the mean number of neutrons emitted per fission (ν)

In order to avoid any misunderstanding of the physical meaning of the different parameters the following 2-group balance equations must be satisfied :

$$D_1 \Delta \phi_1 + (SA1 + SR) . \phi_1 = \frac{1}{K}(NSF1 . \phi_1 + NSF2 . \phi_2)$$

$$D_2 \Delta \phi_2 + SA2\, \phi_2 = SR\, \phi_1$$

with : - zero Buckling
- k : effective multiplication factor

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3. ASSEMBLY TYPES

Three different types of 17 x 17 assemblies are considered which represent UO_2 or MOX fuel elements with guide tubes or rods inserted. A layout of their geometry is given hereafter for each assembly (standard PWR assembly 21.42 cm with a 1.26 cm pitch).

3.1 "UX" Assembly : UO_2 fuel assembly with 24 guide tubes and a central Moveable Fission Chamber

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
01	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
02	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
03	U	U	U	U	U	X	U	U	X	U	U	X	U	U	U	U	U
04	U	U	U	X	U	U	U	U	U	U	U	U	U	X	U	U	U
05	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
06	U	U	X	U	U	X	U	U	X	U	U	X	U	U	X	U	U
07	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
08	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
09	U	U	X	U	U	X	U	U	C	U	U	X	U	U	X	U	U
10	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
11	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
12	U	U	X	U	U	X	U	U	X	U	U	X	U	U	X	U	U
13	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
14	U	U	U	X	U	U	U	U	U	U	U	U	U	X	U	U	U
15	U	U	U	U	U	X	U	U	X	U	U	X	U	U	U	U	U
16	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
17	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U

3.2 "UA" Assembly : UO_2 fuel assembly with 24 AIC and a central Moveable Fission Chamber

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
01	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
02	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
03	U	U	U	U	U	A	U	U	A	U	U	A	U	U	U	U	U
04	U	U	U	A	U	U	U	U	U	U	U	U	U	A	U	U	U
05	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
06	U	U	A	U	U	A	U	U	A	U	U	A	U	U	A	U	U
07	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
08	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
09	U	U	A	U	U	A	U	U	C	U	U	A	U	U	A	U	U
10	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
11	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
12	U	U	A	U	U	A	U	U	A	U	U	A	U	U	A	U	U
13	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
14	U	U	U	A	U	U	U	U	U	U	U	U	U	A	U	U	U
15	U	U	U	U	U	A	U	U	A	U	U	A	U	U	U	U	U
16	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
17	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U

3.3 "PX" Assembly : MOX fuel assembly with 24 guide tubes and a Central Moveable Fission Chamber

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
01	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1
02	P1	P2	P2	P2	P2	P2	P2	P2	P2	P2	P2	P2	P2	P2	P2	P2	P1
03	P1	P2	P2	P2	P2	X	P2	P2	X	P2	P2	X	P2	P2	P2	P2	P1
04	P1	P2	P2	X	P2	P3	P3	P3	P3	P3	P3	P3	P2	X	P2	P2	P1
05	P1	P2	P2	P2	P3	P3	P3	P3	P3	P3	P3	P3	P3	P2	P2	P2	P1
06	P1	P2	X	P3	P3	X	P3	P3	X	P3	P3	X	P3	P3	X	P2	P1
07	P1	P2	P2	P3	P3	P3	P3	P3	P3	P3	P3	P3	P3	P3	P2	P2	P1
08	P1	P2	P2	P3	P3	P3	P3	P3	P3	P3	P3	P3	P3	P3	P2	P2	P1
09	P1	P2	X	P3	P3	X	P3	P3	C	P3	P3	X	P3	P3	X	P2	P1
10	P1	P2	P2	P3	P3	P3	P3	P3	P3	P3	P3	P3	P3	P3	P2	P2	P1
11	P1	P2	P2	P3	P3	P3	P3	P3	P3	P3	P3	P3	P3	P3	P2	P2	P1
12	P1	P2	X	P3	P3	X	P3	P3	X	P3	P3	X	P3	P3	X	P2	P1
13	P1	P2	P2	P2	P3	P3	P3	P3	P3	P3	P3	P3	P3	P2	P2	P2	P1
14	P1	P2	P2	X	P2	P3	P3	P3	P3	P3	P3	P3	P2	X	P2	P2	P1
15	P1	P2	P2	P2	P2	X	P2	P2	X	P2	P2	X	P2	P2	P2	P2	P1
16	P1	P2	P2	P2	P2	P2	P2	P2	P2	P2	P2	P2	P2	P2	P2	P2	P1
17	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1

4. CORE CONFIGURATIONS FOR 2D BENCHMARK CALCULATIONS

Five "core" configurations are proposed for 2 dimensional benchmark calculations. They consist in checker-board assembly configurations with different boundary conditions.

4.1 Checker-board configuration with Uranium UX and UA assemblies

Configuration C1 : **Uranium Infinite Checker-board**

	...	...	...	
... UX	UA	UX	UA	...
... UA	UX	UA	UX	...
... UX	UA	UX	UA	...
	...	...	...	

4.2 Checker-board configurations with Uranium and MOX fuel elements

Configuration C2 : **MOX Infinite Checker-board**

	...	...	...	
... UX	PX	UX	PX	...
... PX	UX	PX	UX	...
... UX	PX	UX	PX	...
	...	...	...	

<u>Configuration C3</u> : Reflected MOX Checker-board

J = 0 (top) · J = 0 (left) · J = 0 (right) · J = 0 (bottom)

UX	PX
PX	UX

J = 0 represents reflexive boundary conditions.

<u>Configuration C4</u> : Semi Reflected MOX Checker-board

J = 0 (top) · J = 0 (left) · PHI = 0 (right) · PHI = 0 (bottom)

UX	PX
PX	UX

J = 0 represents reflexive boundary conditions.
PHI = 0 represents zero flux boundary conditions

<u>Configuration C5</u> : MOX Core configuration

J = 0 (top) · J = 0 (left) · PHI = 0 (right) · PHI = 0 (bottom)

UX	PX	R
PX	UX	R
R	R	R

R : Reflector (see section 2)
Same comments as above for boundary conditions.

For this specific configuration the different partners involved in the benchmark calculations may propose different boundary conditions consistent with the 2 energy groups X-sections given en section 2 (R région).

5. RESULTS PRESENTATION

a - Results and Flux Normalization

- The different partners should give for each of the 5 'core' configurations presented in section 4 :

  - k effective value
  - Mean flux distribution : ϕ_g (i,j)

    e.g. : flux for each energy group (g) and cell (i,j) after integration over space (cell)
  - Mean Production rate distribution : $F(i,j) = NSF1*\phi_1(i,j) + NSF2*\phi_2(i,j)$

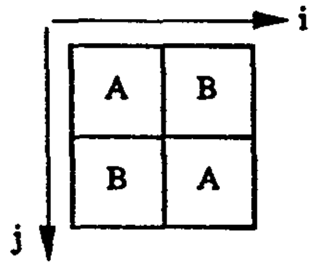
    e.g. : cell by cell Production rate, after integration over space (cell) and energy

- We propose the following flux integral normalization over space and energy :

$$\sum_{i,j \in \mathcal{D}} \frac{1}{K}\left(NSF1\ \phi_1(i,j) + NSF2\ \phi_2(i,j)\right) = 1$$

Where : . ϕ_g (i,j) represents the flux distribution in cell (i,j) and group g,

. $\mathcal{D}$ represents the four 'central' active assemblies of the different checker-board configurations :



Where A/B stand successively for :

. UX/UA for configuration C1

. UX/PX for configurations C2-C5

b - Results presentation

- In order to facilitate intercomparisons, we propose to produce the results on paper and magnetic support (diskette) using the format presented in Appendix. Thus, flux and Production rates should be given on the D domain for the five configurations, extended to the reflector zone for the flux in configuration C5.

c - Time Scale

- Results should be available before the end of December 1991 and sent to :

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6. POSSIBLE EVOLUTION OF THE PRESENT BENCHMARK

On the basis of the results obtained for the present Benchmark calculations, that should give a straight forward intercomparison of different numerical schemes, it would be possible, according to the partners interest, to propose a similar Benchmark based upon the use of a common set of microscopic X-sections for heterogeneous calculations.

Such approach would then lead to an intercomparison of the different steps of a specific calculation route (homogenization, Equivalence, ...).

APPENDIX

FORMAT FOR RESULTS PRESENTATION

In order to facilitate intercomparisons, results should be made available on paper and Magnetic supports using a 'standard' format presented here after.

1. DISKETTE SUPPORT

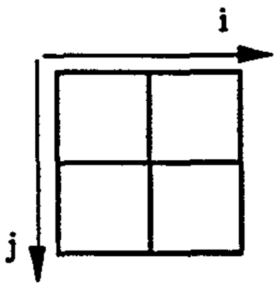
- DISKETTE	SIZE	:	3" 1/2 MS DOS	IBM-PC Compatible (2.1 or over)
- DATA	FORMAT	:	ASCII	
- WRITE	FORMAT	:	Results associated to the 5 core configurations should be sequentially ordered as in Table 1.	

2. PAPER SUPPORT

- The data recorded on Diskette should also be presented on paper, using a similar 'readable' format as in table 1.
  The READ-WRITE programme may also be given.

- In order to permit straight forward intercomparisons flux Traverses should also be given for each configuration using the format presented in Table 2.

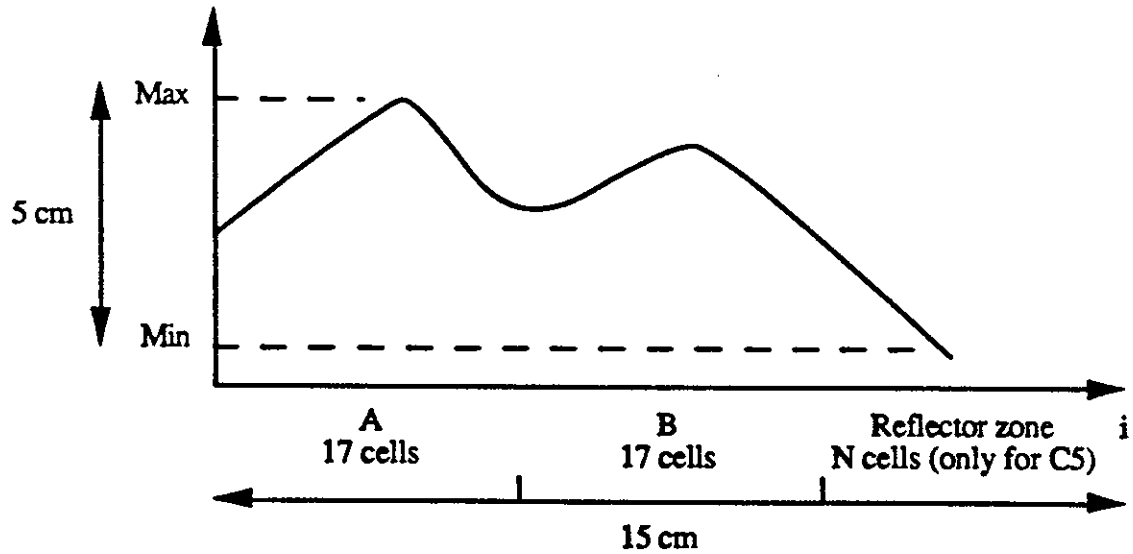
- A short description of the numerical scheme used to run the calculations would also be appreciated.

DATA	DIMENSION	OBSERVATION
TITLE	CHARACTER - 80	Configuration Name - Comment
K	REAL - 1	k - effective
N	INTEGER - 1	Number of Mesh Points or elementary cell considered in the Reflector : $N = 0$ for C1, C2, C3, C4 $N \neq 0$ for C5
R(i)	REAL - N	Mesh size of each of the N points in the reflector along the i-axis (assuming same discretization along j-axis)
ϕ_g (i,j)	REAL - 2312 for C1, C2, C3, C4 REAL - $2 * (34 + N)^2$ for C5	Flux Distribution for the four central active assemblies (and Reflector for configuration C5)  ϕ_g (i,j) cell $i = 1, 34 + N$ $j = 1, 34 + N$ group $g = 1,2$ ϕ_1 (1,1) ... ϕ_1 (34 + N, 1) ... ϕ_1 (1, 34 + N) ... ϕ_1 (34 + N, 34 + N) ϕ_2 (1,1) ... ϕ_2 (34 + N,1) ... ϕ_2 (1, 34 + N) ... ϕ_2 (34 + N, 34 + N)
F (i,j)	REAL 1156	Production rate Distribution Same Format as above

Record Format for Results presentation on Diskette

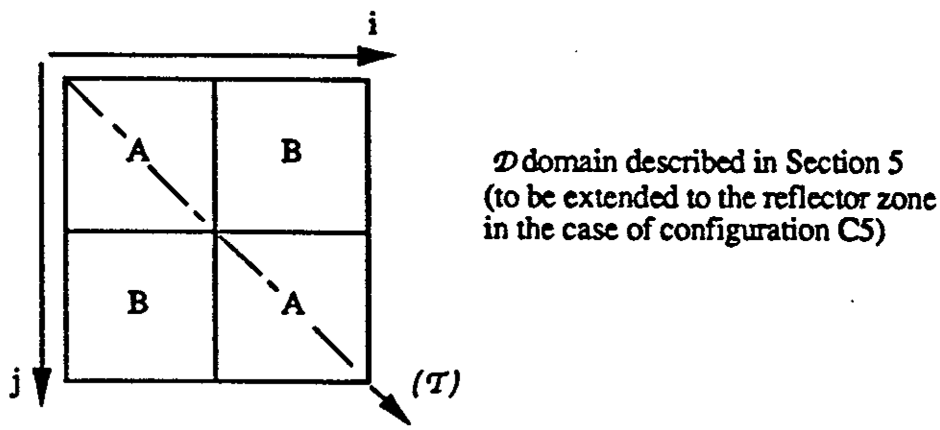
TABLE 1

Display Format



Flux Traverses

For each configuration the 'Diagonal' Traverse ($\mathcal{T}$) should be given in groups 1 and 2 (e.g. to Flux Traverses).



Display Format for flux Traverses

TABLE 2

APPENDIX 1

ADDITIONAL CROSS SECTIONS FOR TRANSPORT CALCULATIONS

On the basis of the following relation between Transport (ST), Absorption (SA) and Scatter (SS) cross sections :

$$ST = SA + (1 - \bar{\mu})\, SS$$

where $\bar{\mu}$ stands for the average cosine deviation angle

We propose to derive transport cross sections from the additional data given hereafter :

cell *	SS	
	group 1	group 2
U	0.54	1.00
P1	0.52	0.90
P2	0.52	0.83
P3	0.52	0.76
X	0.56	1.20
R	0.56	2.30
C	0.56	1.20
A	0.48	0.05

$\bar{\mu}$ (group 1) = 0.50

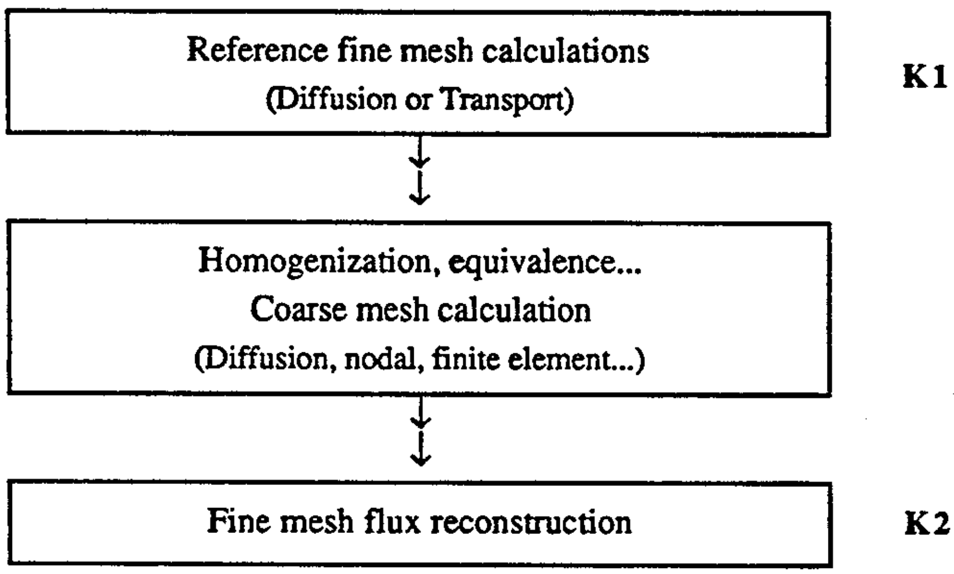
$\bar{\mu}$ (group 2) = 0.30

* see initial specifications

APPENDIX 2

POSSIBLE INTERCOMPARISONS USING DIFFUSION OR TRANSPORT CALCULATIONS

POSSIBLE RESULTS FOR A SPECIFIC CALCULATION ROUTE



POSSIBLE INTERCOMPARISONS

In order to take advantage of the different results that will be produced (Diffusion, Transport...), we propose the participants to present the following sets of results for intercomparison, when available :

- Reference fine mesh calculations **(K1)**
- Fine mesh flux reconstruction **(K2)**

together with a description of the method used for fine flux reconstruction *(see specifications)*.